Abstract

Improvements in computer technology, the need for enhancement of situational awareness in more complex environments, and the rapid growth of commercial air transportation, together with continued military competitiveness, led to increased levels of integration in the cockpit. The Cockpit display systems provides the visible portion of the Human Machine Interface (HMI) by which aircrew manage the modern Glass cockpit and thus interface with the aircraft avionics.

This project is to investigate the cockpit display of the Boeing 777 and the system used to display the operating conditions of the aircraft was studied. The Boeing 777 cockpit is much different than the steam gauges and dials of aircraft from earlier. For the first time, digital computers were used by Boeing engineers to design and electronically pre-assemble the entire airplane, increasing accuracy and improving quality. New laboratory facilities enabled the various airplane systems to be tested together as a single integrated entity in simulated flight conditions -- before the first jetliner took to the air. This allowed a smoother transition to flight testing and service introduction.

The Boeing 777 family is the most technologically advanced family of airplanes in the world. The 777 seats from 301 up to 368 passengers in a three-class configuration with a range of 5,210 nautical miles (9,649 km) for the 777-200 to 9,420 nautical miles (17,446 km) for the 777-200LR World liner (Longer Range). The 777's Landing Gear is the largest ever incorporated into a commercial jetliner. With six wheels on each main landing gear and two wheels on the nose gear, it has an unmistakable footprint.

INVESTIGATION OF BOEING 777 COCKPIT DISPLAY

Cockpit Display System

The Cockpit display systems (CDS) provides the visible (and audible) portion of the Human Machine Interface (HMI) by which aircrew manage the modern Glass cockpit and thus interface with the aircraft avionics.

Prior to the 1970s, cockpits did not typically use any electronic instruments or displays. Improvements in computer technology, the need for enhancement of situational awareness in more complex environments, and the rapid growth of commercial air transportation, together with continued military competitiveness, led to increased levels of integration in the cockpit.

The average transport aircraft in the mid-1970s had more than one hundred cockpit instruments and controls, and the primary flight instruments were already crowded with indicators, crossbars, and symbols, and the growing number of cockpit elements were competing for cockpit space and pilot attention.

History and Overview of Boeing777

At the beginning of the "Jet Age" in the late 1950s and early 1960s, speed was the paramount consideration between jetliners. Early airliners such as the Boeing 720 could cruise up to Mach 0.90, and the Convair 990 reached speeds up to Mach 0.97. The oil crisis of 1973 accelerated a trend that began with the Boeing 747 – a trend towards larger, more economical airliners.

In the 1980s, airlines started to make extensive use of "big twin" aircraft such as the Boeing 757, 767 and Airbus 300 to deliver large passenger loads without the high operating costs of the aircraft they replaced, such as the 727, DC-10 and DC-8. Today, Delta's trans-oceanic flights are dominated by the Boeing 767, 757 and 777.

The airplane is larger than all other twinjet or tri-jet airplanes, yet smaller than the 747 and it brings the twin-engine economic advantage to medium- and long-range markets. The 777 currently is available in five models: 777-200, 777-200ER (extended range), 777-200LR (longer-range), 777-300 and the 777-300ER. The 777s seat from 301 to 368 passengers in a three-class configuration with a range of 5,210 nautical miles (9,649 km) in the 777-200 to 9,395 nautical miles (16,316 km) for the 777-200LR (longer range) model. Boeing 777's Landing Gear is the

largest ever incorporated into a commercial jetliner. With six wheels on each main landing gear and two wheels on the nose gear, it has an unmistakable footprint.

The 777 program was launched in October 1990 with an order from United Airlines. In June 1995, United flew its first 777 in revenue service. On June 26th, 1995, the Boeing board of directors authorized production of the 777-300. The first 777-300 was delivered to Cathay Pacific Airways in June 1998. The 777-300 is a high-capacity, stretched version of the newest twin-aisle jet. This newest member of the 777 family is "market- driven" to meet airline demand for a jetliner sized to replace older twin-aisle airplanes. The 777-300 complements the existing range of available 777 models with another set of mission capabilities for the world's carriers and offers an attractive option for progressively lower costs per seat within the 777 family.

Main Panel

Fig-1 Main Panel

The 777 cockpit is much different than the steam gauges and dials of aircraft from earlier eras. Three LCD's, called Multifunction Displays are capable of doing the work of multiple gauges in the cockpit.

1. Multifunction Displays (MFD's).
2. Autopilot Panel (Mode Control Panel, MCP)

3. Overhead Panel
4. Backup artificial horizon, altimeter and airspeed indicator.
5. Radio stack and pedestal
6. Engine Start/Stop, Brakes, Landing Gear and Trim

Multifunction Displays (MFD'S)

The three primary MFD's are the Navigation Display, Primary Flight Display, and EICAS as described below.

Navigation Display

The middle MFD can be controlled by the white knob below it. By clicking on the right side of the knob, the MFD will cycle through various views of the HSI. These are shown below. When a NAVAID frequency is dialed into the NAV1 radio, the navigation display will show the Navaid code, frequency and DME.

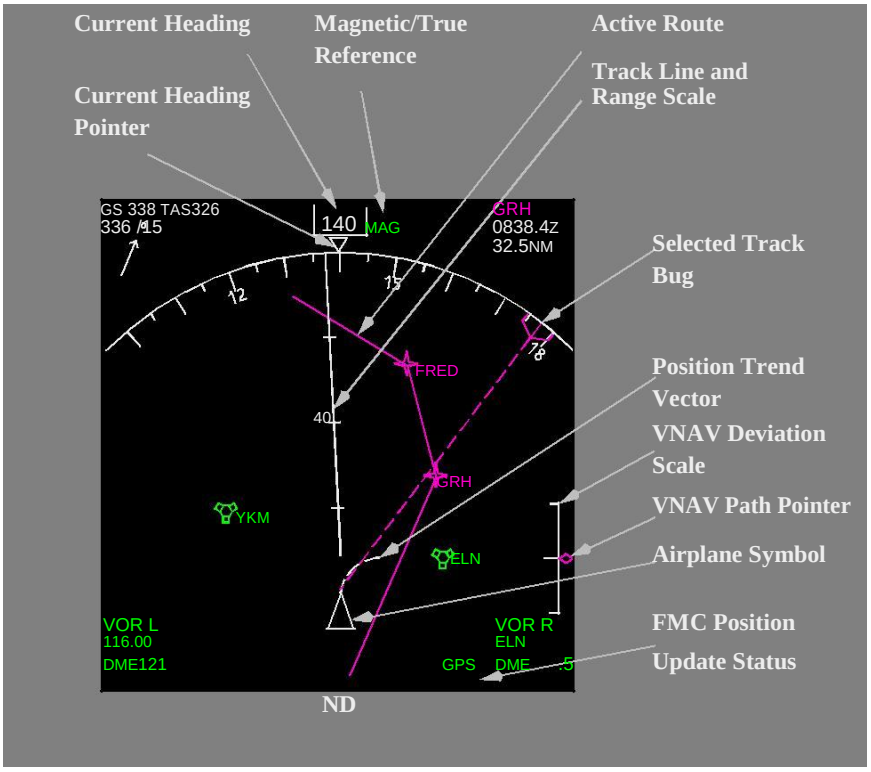

Fig-2 Heading Up Display

ND Weather Radar System Display Indications

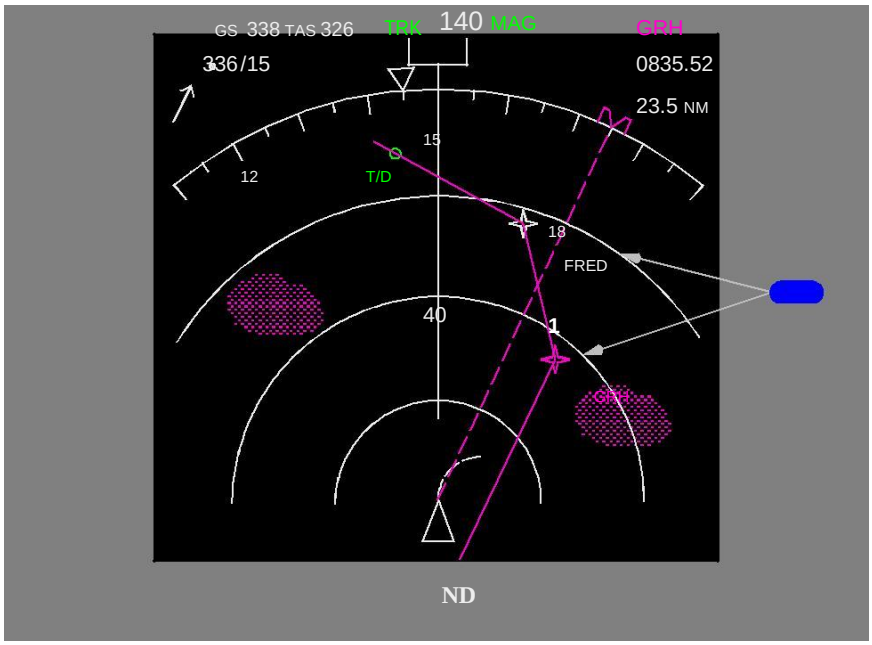

Fig-3 ND Weather Radar System Display Indications

1 **TCAS/Weather Radar Range Arcs**

- Three range arcs in place of the range scale tics on map when TCAS, weather radar, or terrain is selected.

EFIS Control Panel ND Controls

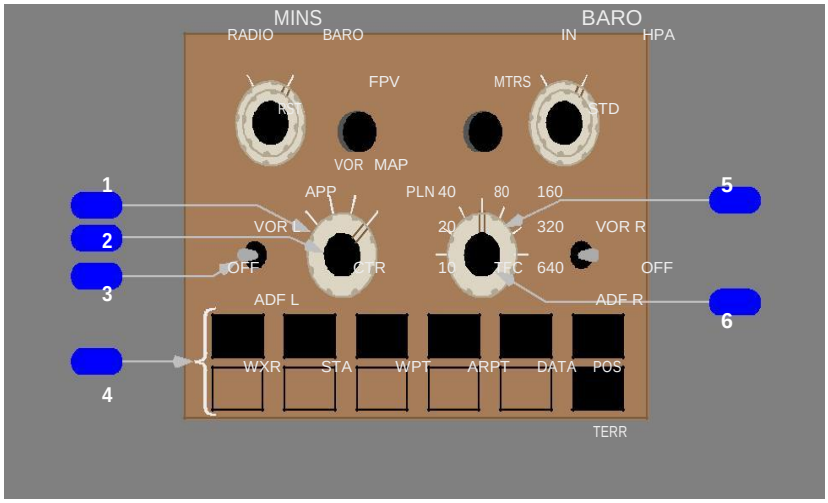

Fig-4 EFIS Control Panel ND Controls

1 **ND Mode Selector (outer)**

Selects the desired ND map display.

- APP
  - Displays localizer and glideslope information in heading–up format
  - Displays reference ILS receiver, ILS frequency or identification, course, and DME
  - Weather radar and TCAS are not displayed in CTR APP mode.
- VOR
  - Displays VOR navigation information in heading–up format
  - Displays reference VOR receiver, VOR frequency or identification, course, DME, and TO/FROM indication
  - Weather radar and TCAS are not displayed in CTR VOR mode.
- MAP
  - Displays FMC–generated route and map information, airplane position, heading, and track
  - Displays waypoints, including the active waypoint, within the selected range
  - Displays VNAV path deviation.
- PLN
  - Displays a nonmoving, true north–up, route depiction
  - The airplane symbol represents actual airplane position
  - Allows route step–through using the CDU legs page
  - Weather radar and TCAS are not displayed in PLN mode.

2 ND Center (CTR) Switch (inner)

- Push
  - Subsequent pushes alternate between expanded and centered displays

3 VOR/ADF Switches

- Displays VOR or ADF information on the respective ND.
- VOR displays the VOR pointer, VOR frequency or identification and associated DME information in all modes except PLAN.

4 **Map Switches**

- The map switches:
    - Select detailed ND information displays
    - Displays can be selected simultaneously
    - Second push removes the information.
- WXR (weather radar)
    - Display weather radar information, Flight Management and Navigation. Also displays range information when in the expanded APP or VOR modes.
- STA (station)
    - Displays high and low altitude navigation aids, if the ND range selector is in the 10, 20 or 40 NM range
    - Displays high altitude navigation aids, if the ND range selector is in the 80, 160, 320, or 640 NM range.
- WPT (waypoint)
    - Displays waypoints, if the ND range selector is in the 10, 20 or 40 NM range.
- ARPT (airport)
    - Displays airports on all ranges.
- DATA
    - Displays the FMC estimated time of arrival, altitude at each waypoint, and altitude constraints at each waypoint.
- POS (Position)
    - Displays ADIRU and GPS positions
    - Displays VOR raw data radials extended from the nose of the airplane
- TERR (terrain)
    - Displays terrain data.

5 ND Range Selector (outer)

- Selects the desired ND nautical mile range scale.

6 ND Traffic (TFC) Switch (inner)

- Push
    - Displays TCAS ND information and displays range information.

Primary Flight Display

The left MFD is the primary flight display. Its primary indicators are indicated airspeed, pitch, attitude, and altitude. It also displays heading, rate of climb/descent, and mode of flight. The Primary flight display is shown below.

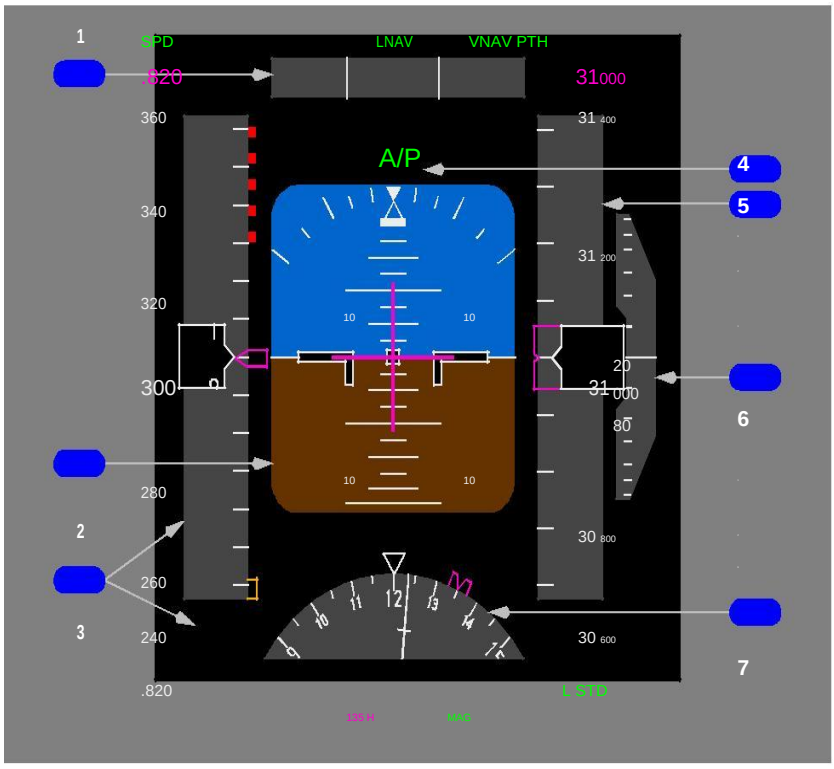

Fig-5 Primary Flight Display

1 Flight Mode Annunciations

2 Attitude, Steering, and Miscellaneous Indications

- Displays ADIRS attitude information

3 Airspeed/Mach Indications

- Displays air data inertial reference system (ADIRS) airspeed information and other airspeed related information.

4 Autopilot, Flight Director System Status

5 Altitude Indications

- Displays ADIRS altitude and other altitude–related information

6 Vertical Speed Indication

7 Heading and Track Indications

PFD Instrument Landing System Indications

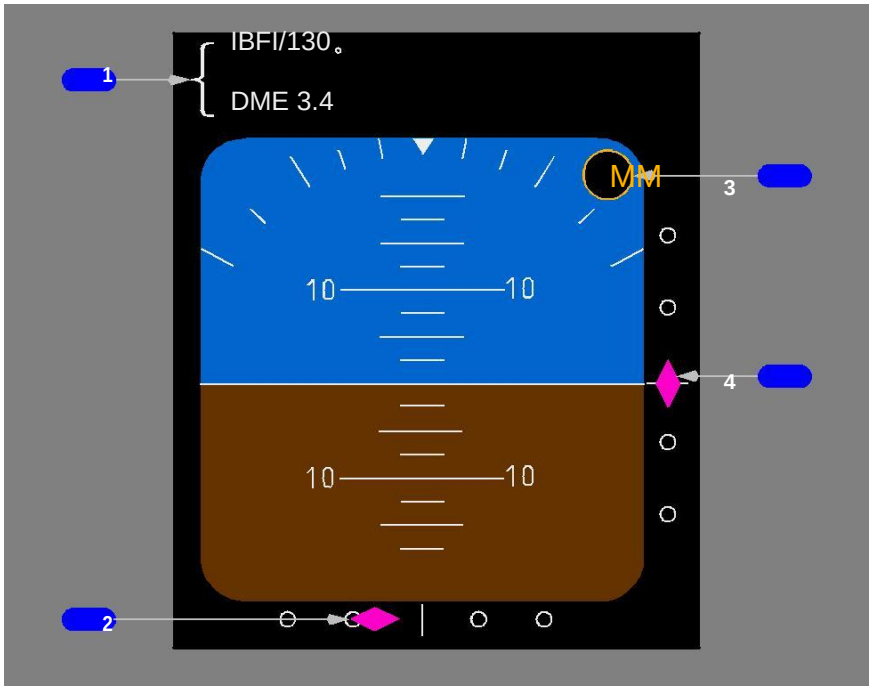

Fig-6 PFD Instrument Landing System Indications

1 Approach Reference

- Display the selected ILS identifier or frequency, approach front course and ILS DME distance.
- If the tuned ILS frequencies disagree, the frequency turns amber with an amber horizontal line through it.
- If the approach courses in the ILS receivers disagree, the course turns amber with an amber horizontal line through it.

2 Localizer Pointer and Scale

- The localizer pointer:
  - Indicates localizer position relative to the airplane
  - Is in view when the localizer signal is received
  - Fills in solid when within 2 1/2 dots from the center
- The scale is in view after the frequency is tuned.
- At low radio altitudes, with the autopilot or flight director engaged, the scale turns amber and the pointer flashes to indicate excessive localizer deviation.

- At low altitudes, with LNAV engaged and LOC armed, the localizer scale turns amber and the pointer flashes if the localizer is not captured.

3 Marker Beacon Instrument

- The marker beacon indication appears flashing when over one of the marker beacon transmitters:
  - IM – an airway or inner marker beacon
  - MM – a middle marker beacon
  - OM – an outer marker beacon
- The indication flashes in cadence with the beacon identifier.

4 Glideslope Pointer and Scale

- The glideslope pointer:
  - Indicates glideslope position relative to the airplane, and:
  - Is in view when the glideslope signal is received
  - Fills in solid when within 2 1/2 dots from the scale center.
- The scale is in view after the frequency is tuned.
- At low radio altitudes, with the autopilot or flight director engaged, the scale turns amber and the pointer flashes to indicate excessive glideslope deviation.

PFD Rising Runway Indications

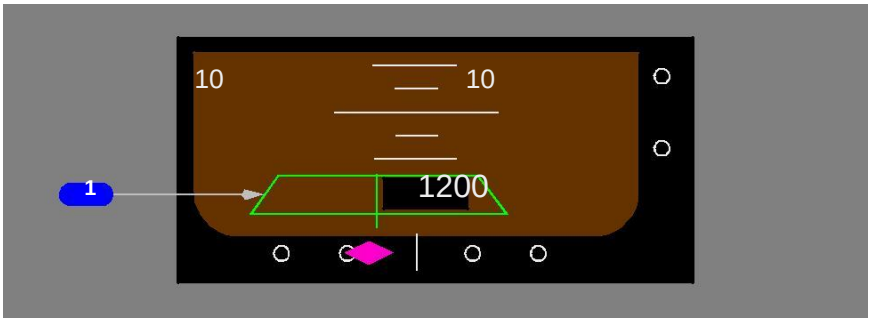

Fig-7 PFD Rising Runway Indications

1 Rising Runway

- Displayed below 2500 feet radio altitude when the localizer pointer is in view for both front and back courses.

- Moves toward the airplane symbol below 200 feet radio altitude.
- The stem of the rising runway symbol flashes when localizer deviations cause the diamond to flash.

PFD Altitude Indications

1 Selected Altitude Bug

- Indicates the altitude set in the MCP altitude window.
- When the selected altitude is off scale, the bug is parked at the top or bottom of the tape, with only one half the bugs visible.

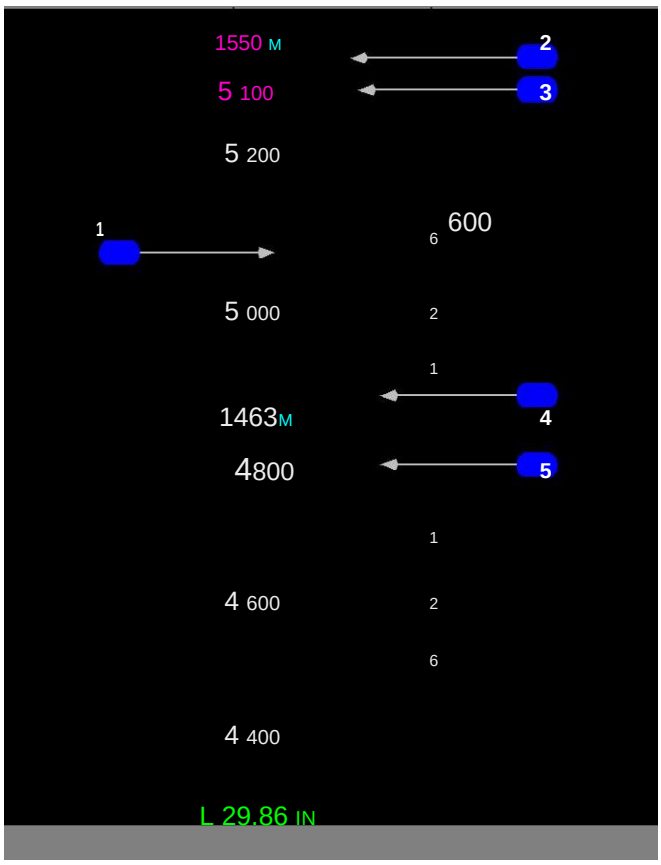

Fig-8 PFD Altitude Indications

2 Selected Altitude – Meters

- Display when MTRS is selected on the EFIS control panel MTRS switch. Indicate selected altitude in meters (selected in feet in the MCP altitude window).

3 **Selected Altitude**

- Displays the altitude set in the MCP altitude window.
- The selected altitude box is highlighted in white between 900 feet and 200 feet prior to reaching the selected altitude.

4 **Current Altitude – Meters**

- Display when MTRS is selected on the EFIS control panel MTRS switch. Display altitude in meters.

5 **Current Altitude**

- Indicates current ADIRS altitude.

EICAS

The left MFD, the right MFD, which displays the Engine Indicating and Crew Alert System (EICAS), can be adjusted to display different information. The display is adjusted using the white knob furthest to the left as indicated below.

Fig-9 EICAS

The primary EICAS screen displays EPR, N1, EGT, Flap Indicator, and Fuel and can be cycled using the knob highlighted above through various types of displays. The above screenshot shows the engine/fuel data screen and the control knob. The fleet installer is not equipped with a TCAS display. However, TCAS is typically indicated on the Navigation Display.

Autopilot Control Panel

Fig-10 Autopilot Control Panel

1. Autopilot Master Switch

- ON: Activates the Auto-pilot system
- OFF:Deactivates the Auto-pilot system

2. Flight Director Switch

- ON: Displays the flight director command bars on the associated ADI turn on the F/D switch on the ground with no autopilots engaged. If no autopilot is engaged, the flight director defaults to heading hold and vertical speed mode.
- OFF: Turns off the flight director display bars on the ADI

3. SPD Hold

- Pushing the SPD switch will cause the auto throttle to hold speed displayed in the airspeed indicator, subject to maximum speeds.
- Speed is displayed in ADI

5. Mach Hold

- Pushing switches between air speed setting and Mach number. Twisting knob adjusts for both.

6. GPS Switch

- Holds the aircraft of the GPS Route entered into the GPS System. The GPS switch is not label in the graphic above. It is the POS switch just to the left of the Flight Director Button.

7. NAV Switch

- Holds the aircraft heading at the course entered or, in combination with the GPS switch, direct the aircraft to follow the flight plan entered in the flight planner. If no flight plan is entered or loaded, there is no guarantee that the aircraft will fly you to your destination.

8. APR Hold

- Armed the AFDS to capture and fly the localizer and glide slope. The correct NAV1 frequencies and approach heading must be entered for this mode to work properly. Your experience may vary and this type of approach in the fleet installer is not a guaranteed auto land.
- Glide slope will not capture if intercept angle is greater than 80 degrees.
- Approach mode allows for multiple autopilots to be armed for autoland and rollout.

9. FLCH LVL Switch

- The flight change level switch does not operate as it does in most payware FMC applications. Flight level and vertical speed should be controlled manually or using the autopilot digital dials mentioned below.

10. Heading Bug

- The heading bug will adjust the heading of the aircraft or VOR direction depending upon the operation of the aircraft within the other modes of flying. While flying in autopilot heading mode, this dial will directly control the course the aircraft flies.

12. HDG Heading Hold Button

- The heading hold button will maintain the aircraft flying the heading above it when activated.

12. Vertical Speed Switches

- Top
    - Changes the vertical speed which is displayed on the VSI
- Bottom
    - Press to engage vertical speed mode. V/S is displayed on each ADI. When pressed the autopilot/FD will maintain vertical speed displayed on VSI.

13. Yaw Damper

- The Yaw Damper switch activates the yaw damper which is required for autopilot to function. The yaw damper on an aircraft is required to reduce the yawing and rolling oscillations during flight.

14. Altitude Selector and Hold Button

- Cursor of left or right of knob to change altitude setting, push “Hold” button to hold specified altitude.

15. Localizer Course Button

- Theoretically holds back-course of established Localizer (NAV1 tuned).

16. Approach Course Button

- Both the localizer and approach course buttons are designed to hold the aircraft on the ILS glide slope and path. This feature in the simulator is unstable and should not be relied upon for autoland sequences.

Overhead Panel

Fig-11 Overhead Panel

The overhead panel in the 777-fleet installer operates the de-icing and lighting systems. Alternatively, there is an additional yaw damper switch labeled “YD” which can be used in lieu of the aforementioned autopilot panel.

Cathode Ray Tube Screens

Although these displays resemble conventional cathode ray tube (CRT) screens, they incorporate advanced liquid-crystal display technology. The depth of the new "flat panel displays" is about half that of CRTs.

In addition to saving space, the new displays weigh less and require less power. They also generate less heat; which contributes to greater reliability and a longer service life. As another benefit, the displays do not require the heavy, complex Air Conditioning apparatus needed to cool equipment on previous flight decks. Pilots appreciate that flat panel displays remain clearly visible in all conditions, even direct sunlight.

Control Display Units

Three multipurpose Control Display Units (CDUs), installed in the center aisle stand, provide data display and entry capabilities for flight management functions. These units are the primary interface with an integrated Airplane Information Management System (AIMS). The

CDUs have color displays, again in response to market preferences. Adding color allows pilots to assimilate the information more quickly.

The flight crew transmits control and maneuvering commands through electrical wires, augmented by computers, directly to Hydraulic actuators for the Elevators, Rudder, Ailerons and other control surfaces. This three-axis "fly-by-wire" flight control system saves weight, simplifies factory assembly compared to conventional mechanical systems relying on steel cables, and requires fewer spares and less maintenance in airline service.

EGPWS

The 777 was the first Boeing model to be equipped with the Enhanced Ground Proximity Warning System (EGPWS) as standard equipment. The EGPWS displays potentially threatening terrain and gives an audible alert up to a minute in advance of possible terrain conflict, compared with 10 to 15 seconds for previous systems. It incorporates a proprietary digital terrain map, which it continuously compares to aircraft position data from the navigation system.

GMCS

One new feature in the 777-300 flight deck is the addition of a Ground Maneuver Camera System (GMCS), designed to assist the pilot in ground maneuvering of the 777-300 with camera views of the nose gear and main gear areas. The cameras are on the leading edge of the left and right horizontal stabilizers and the underside of the fuselage. The images are displayed at the Multi-Functional Display positions in the flight deck in a three-way split format.

Standby Flight Instruments

- The standby flight instruments include the:
    - Integrated standby flight display
    - Standby magnetic compass
- The standby attitude, airspeed, and altimeter indicators are small flat panel liquid crystal displays units.

1 **Integrated Standby Flight Display (ISFD)**

- Provide an independent source of attitude, airspeed and altitude information.

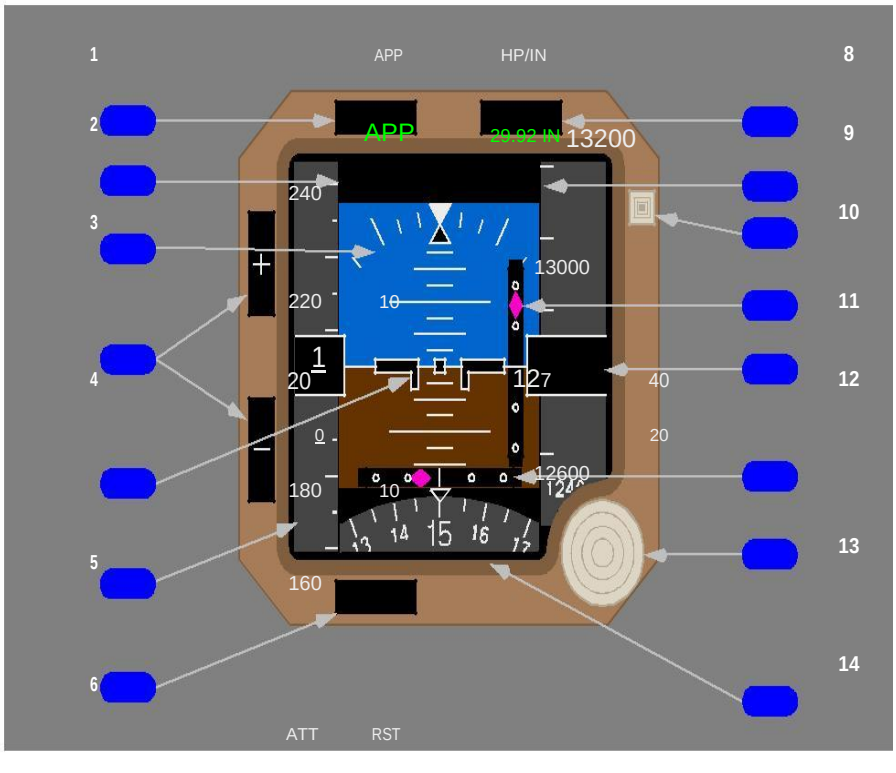

Fig-12 Integrated Standby Flight Display

1 Approach (APP) Switch

- Push
  - When blank, selects APP
  - When APP displayed, selects BCRS
  - When BCRS displayed, blanks

2 Approach Mode Annunciation

- Indicates approach mode selected.
  - Indicates the mode operated
- Blank
  - No approach deviation data displayed.
- APP
  - ILS localizer and glideslope deviation data displayed.
- BCRS (back course)
  - Reverses sensing for localizer pointer during back course approaches.

3 Attitude Display

- Displays airplane attitude.
- Indicates bank in reference to the bank scale. Indicates the horizon relative to the airplane symbol.
- Beyond 30 degrees pitch, large red arrowheads (V-shaped) indicate the attitude has become excessive and the direction to the horizon line.

4 Display Brightness Switches

- Push
    - + Increases display brightness
    - Decreases display brightness.

5 Airplane Symbol

- Indicates airplane position with reference to the horizon.

6 Airspeed Indications

- Indicates airspeed when above 30 knots.

7 Attitude Reset (ATT RST) Switch

- Push and hold at least two seconds
    - Aligns horizon with the airplane symbol
    - Reset takes approximately ten seconds
    - Starts new initialization sequence if previous attempt failed (ground only).

8 Hectopascal/Inch (HP/IN) Switch

- Push
    - Changes units of barometric reference

9 Barometric Setting

- Indicates the barometric setting selected with the barometric selector.
- STD is displayed when selected with the barometric selector

10 Ambient Light Sensor

- Automatically adjusts display intensity for ambient lighting condition
- Based on colors is identified

11 Glideslope Pointer and Scale

- The glideslope pointer indicates glideslope position relative to the airplane -
    - The pointer is in view when the glideslope signal is received

- The scale is in view when the APP mode is selected
- The pointer and scale are removed when the BCRS mode is selected

12 Current Altitude

- It gives the attitude of flying

13 Localizer Pointer and Deviation Scale

- The localizer pointer indicates localizer position relative to the airplane -
  - The pointer is in view when the localizer signal is received
  - The scale is in view when either the APP or BCRS mode is selected.

14 Barometric Selector (BARO)

- Rotate
  - Changes barometric setting.
- Push
  - Selects standard barometric setting (29.92 inches Hg/1013 HPA)
  - If STD displayed, selects the preselected barometric setting.

15 Heading Indication

- Displays airplane heading.

Standby Magnetic Compass

- Display magnetic heading
- Provides appropriate heading corrections

Conclusion

The cockpit display of the Boeing 777 was investigated and the system used to display the operating conditions of the aircraft was studied. The Boeing 777 cockpit is much different than the steam gauges and dials of aircraft from earlier. Three LCD's, called Multifunction Displays are capable of doing the work of multiple gauges in the cockpit. The Multifunction Displays (MFD's), Autopilot Panel (Mode Control Panel, MCP), Overhead Panel, Backup artificial horizon, altimeter and airspeed indicator, Radio stack and pedestal and Engine Start/Stop, Brakes, Landing Gear and Trim are used.

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